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Shelter belt surveys in Kent (with an Appendix on Wind-loading on Artificial Windbreaks)

Agricultural Memorandum No. 832

As a oontribution to a 'Windbreak Workshop' organised by ADAS Maidstone at Brogdale NFT in April 1978, measurements were made in the vicinity of natural shelterbelts at several sites over the latter half of 1977.

Three situations were studied.

1. At Brogdale:

   i. a north-south orientated Poplar (decidous) shelterbelt of height about 10 m and length 150 m.

   ii. an east-west orientated Leyland Cypress belt height 5 m and length about 150 m some 400 into south of site i).

2. At Westmarsh (near Manston):

A commercial orchard site (East Kent Packers). Poplar shelterbelts 10 m height divided the orchard into a 'lattice' with sides between about 50 to 100 m.

At both sites a combination of instruments was used:-
'run of wind' cup-counter anemometers exposed at 2 m; raingauges; 5 cm soil thermometers; maximum and minimum thermometers exposed in 'cocoa-tin' mounts

The siting of instruments is sketched in the figures 1a, b. At Brogdale site A was within a row of young apple trees; sites B to G were on bare earth. Sites J to M were within rows of young apple trees. H was in a gap between the end of the Leyland belt and a belt of 2 to 3 m high trees following the (N to S) field boundary.

At the Westmarsh site P was adjacent to open marsh land to the North; Q and R were in gaps within rows of mature apple trees (of about 2 m height).

Data acquisition and analysis

In the Brogdale shelter survey instrument readings were made at 0900 and 1600 GMT. In the light of 'spot' 0900 wind direction readings at Brogdale and Daily Weather Report wind readings from Gatwick and Manston, data were catagorised into periods with well defined westerlies and northerlies (> 5 knots).

i. Runs of wind at sites B to G during a westerly period (240-300°). were expressed as a percentage of corresponding readings at the up-wind site A.

Results divided clearly into two groups; August and September (5 cases) - full leaf cover, and November and December (7 cases) - leaves shed.

Results, presented graphically, in Fig 2a show the 'seasonal' effect. Wind reductions of 20% or so are still apparent at 15 x belt height during both periods. (Accelerated airflow at G in the winter months is indicated).

ii. For the evergreen survey 9 north to north easterly winds (010 to 040°) situations were extracted and the runs of wind at sites H to M expressed as a percentage of the upwind site E (some 400 m north of belt).

Results, presented in Fig 2b, show the classic influence of the denser shelterbelt - substantial wind reductions (up to 80%) within 4'h' of the belt and a quick recovery to free-stream flow (20% reduction at 10 h, less than 10% at 15 h). No turbulence measurements were attempted.

2. The Westmarsh readings were made at 0730 GMT. Table 1 expresses run of wind at sites P, Q and R as a percentage of that at Manston for various directions.

The exposed nature of P to winds from the west through north to north-east can be seen. Winds within the orchard complex were between 1/10 to 1/20 of that at Manston (at 10 m) and 1/3 and 1/6 of those at P.

Note: at both Brogdale and Westmarsh, temperature readings (soil and air) gave no consistent variations between sites. Similarly for rainfall at Brogdale.

Table 1. Westmarsh

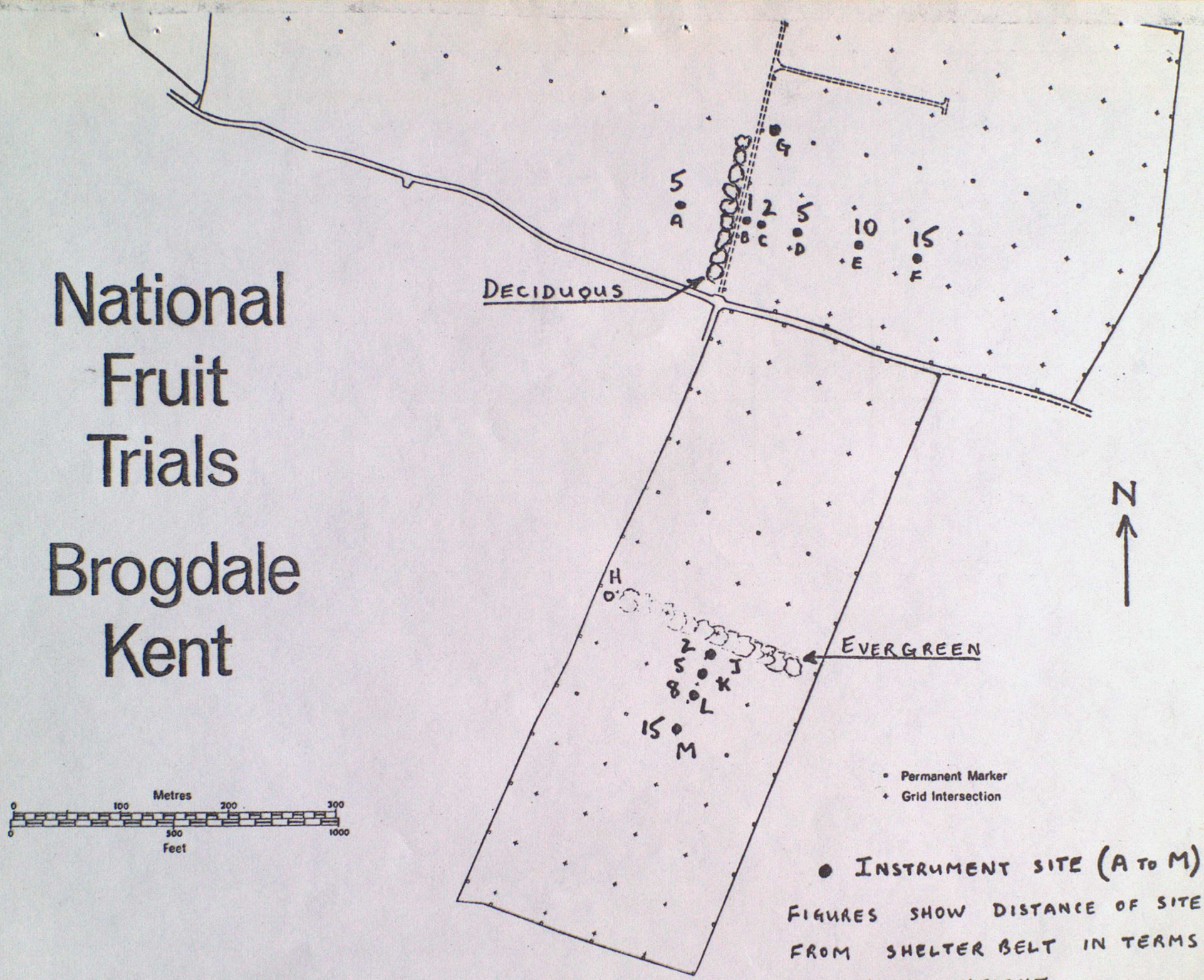
Direction	S_P/S_M	S_Q/S_M	S_R/S_M	S_Q/S_P	S_R/S_P
N - NE	0.38	0.19	0.11	0.50	0.29
NE - E	/	/	/	/	/
E - SE	/	/	/	/	/
SE - S	0.19	0.12	0.04	0.63	0.21
S - SW	0.30	0.20	0.07	0.67	0.23
SW - W	0.24	0.18	0.07	0.75	0.29
W - NW	0.40	0.22	0.06	0.55	0.15
NW - N	0.50	0.13	0.09	0.26	0.18

$S_{P,Q,R}$: 24 hour run of wind at sites P, Q and R (2 metres)

S_M : " " " " " " Manston (10 metres)

National Fruit Trials

Brogdale Kent

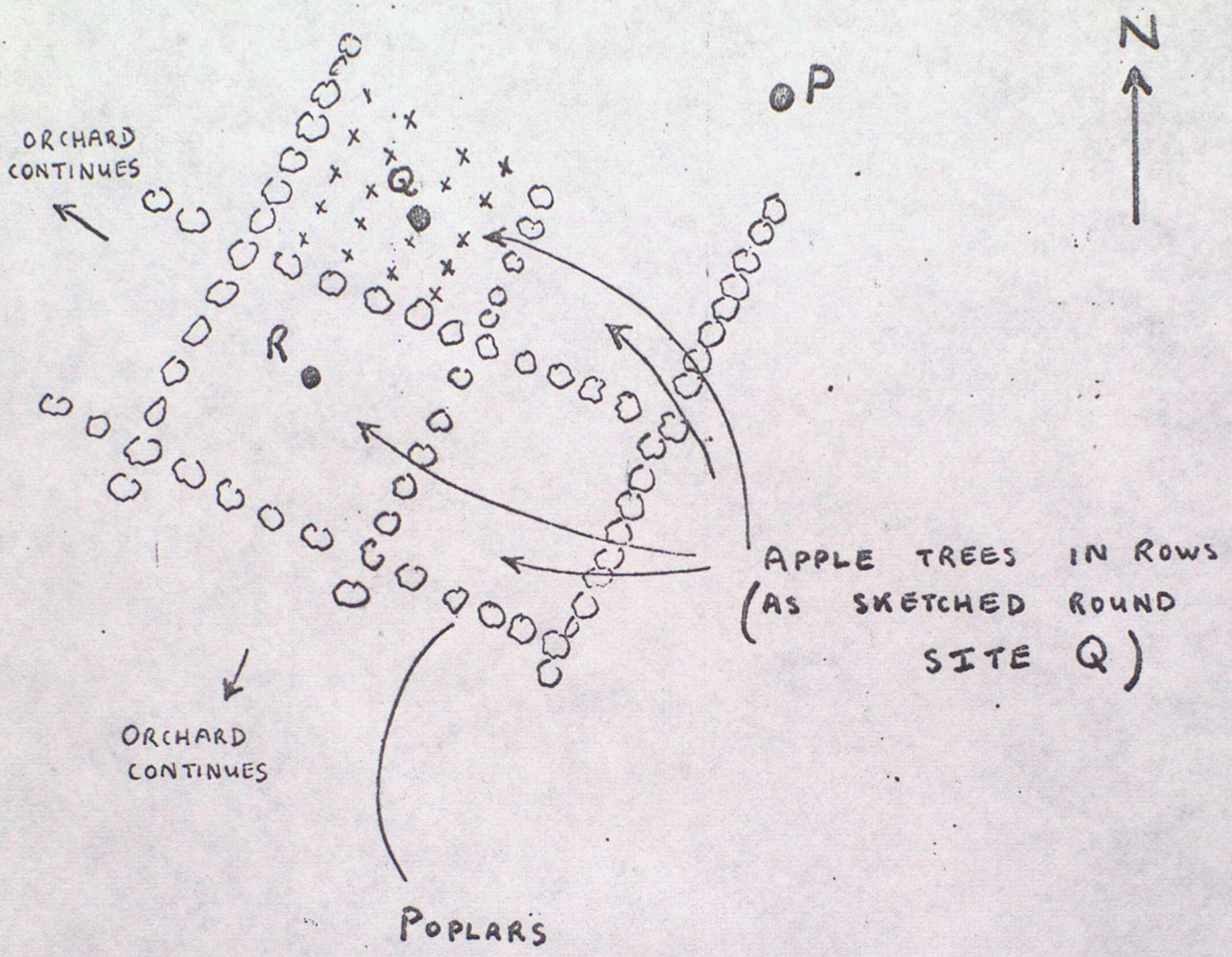


● INSTRUMENT SITE (A TO M)
FIGURES SHOW DISTANCE OF SITE FROM SHELTER BELT IN TERMS OF BELT HEIGHT.

Fig 1a.

Fig 1b.

WESTMARSH



P : EXPOSED TO THE NORTH

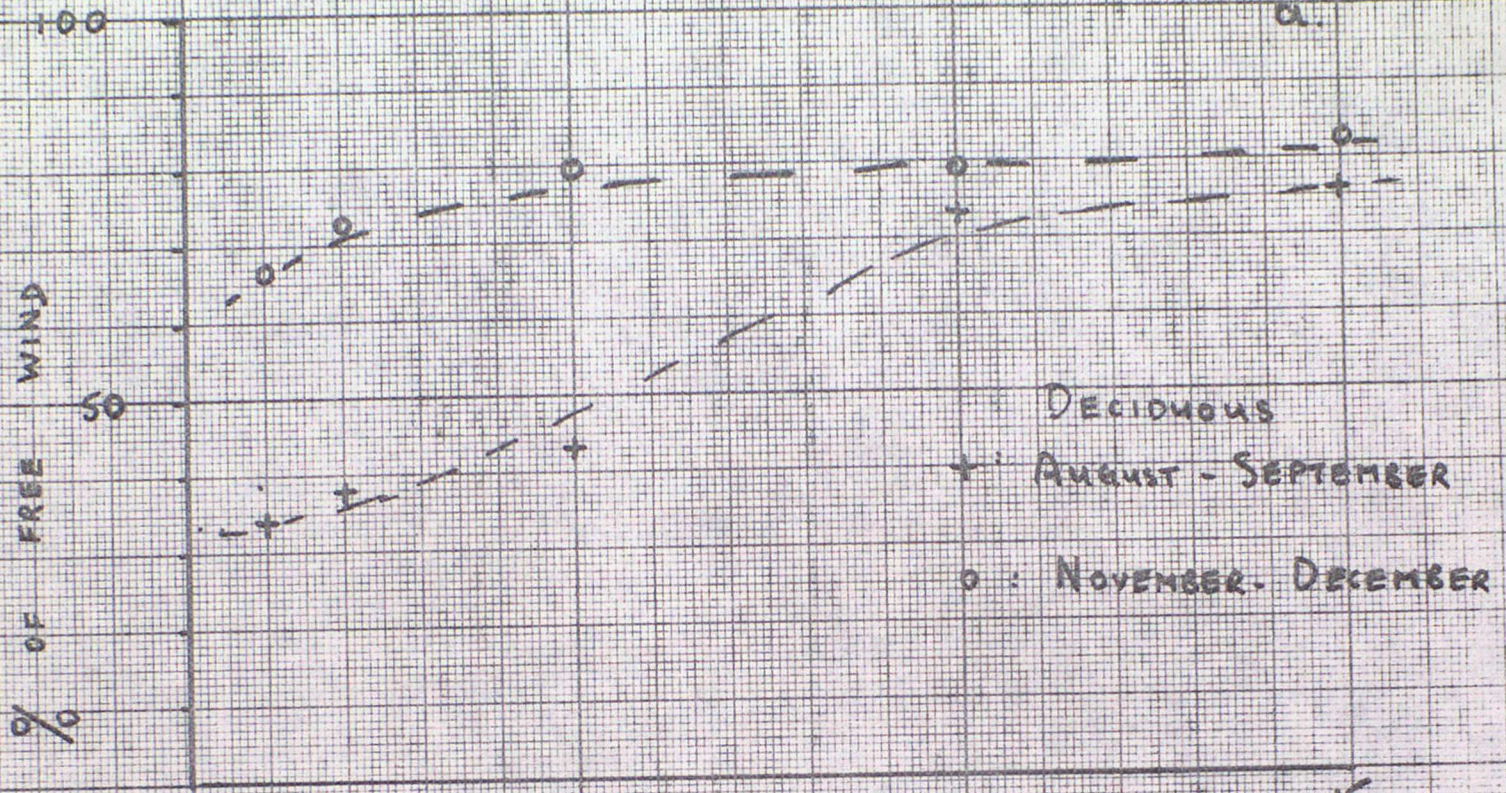
Q : SURROUNDED BY ORCHARD BUT NO POPLAR SHELTER BELT TO NORTH-EAST

R : COMPLETELY SHELTERED.

FIG. 2

BROGDALE 1977

a.



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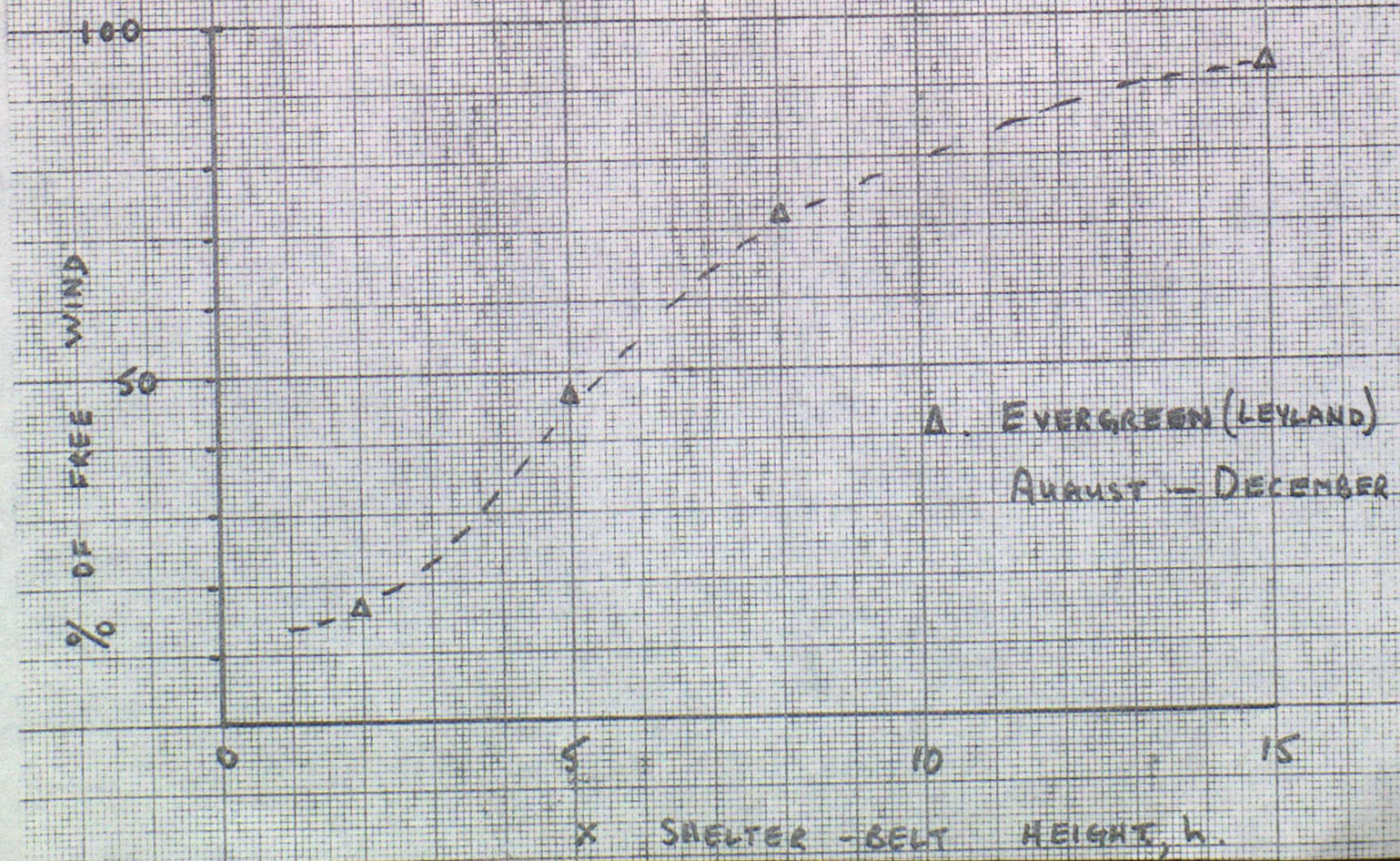


Appendix

Wind-loading on Artifical Windbreaks

The wind-loading can be estimated, for example, for the 1 in 50 year (or, more usefully perhaps, the 1 in 5 year) wind gust using concepts developed in the BSI Code of Practice 3, Chap V part 2 1972 (referred to within text as CP3) and the BRE 'Wind-loading handbook' HMSO 1974.

Introduction

The artificial windbreak in its usual form may be classified aerodynamically as an 'unclad, single frame structure'. That is: the airflow is diverted around individual elements, which all lie in one plane. The wind load on such a frame is calculated for the condition of wind blowing in a direction normal to the plane of the frame.

The load on single frame of elements is:

$$F = C_f \, q \, A_e \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

C_f is the force coefficient, which depends on the porosity or 'solidity ratio' and the type of member (flat or round)

A_e is the 'effective area' on which wind acts.

q is the 'dynamic pressure' of the wind.

Force coefficients C_f for single frames are as follows for flat sided members: (CP3, Table 20).

Table 1.

Solidity ratio	0.1	0.2	0.3	0.4	0.5	0.75	1.0
C_f	1.9	1.8	1.7	1.7	1.6	1.6	2.0

Thus for a wind break of 'porosity' 0.5 we note that $C_f = 1.6$ and $A_e = 0.5$.

The 'dynamic pressure' q is derived from the value of the design wind speed V_s using the equation:

$$q = K V_s^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

K being a constant

Design wind speed V_s

Before q can be evaluated, therefore, V_s must be calculated from

$$V_s = V \times S_1 \times S_2 \times S_3 \qquad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Now V is the 3 second gust speed estimated to be exceeded on the average once in 50 years, at 10 metres above ground in an open situation, and is mapped in Fig 1.

S_1, S_2 and S_3 are 'design wind speed factors', which adjust for topography, ground roughness and height above ground and for the period of years respectively.

Topography factor S_1 deals with effects of hills and valley shelter and is tabulated as follows (CP3 table 2).

Table 2

Topography	S_1
Very exposed hill slopes Valleys producing wind funnelling	1.1
Steep sided, enclosed valleys	0.9
All other cases	1.0

Ground roughness, building size and height above ground, factor S_2

It might be expected that windbreaks would be required in situations defined in CP3 as 'ground roughness 1': open, level country (eg coastal fringes, fens, moorland) and 'ground roughness 2': flat or undulating country with a few hedges and walls, scattered trees and buildings (eg most farmland and estates). Ground roughness factors 3 and 4 denote surfaces with numerous large obstructions and range from well wooded areas, to built-up areas to centres of towns and cities.

The 'type of building' or 'cladding' puts windbreaks into Class A i.e. 'individual members of unclad structures' (CP3 page 10).

The values of S_2 for variation of wind speed above ground for ground roughness catagories 1 and 2 and building Class A are given in the following table 3 (CP3 Table 3).

Table 3 Factor S_2 for Class A 'structures'

Ground Roughness	1 Open Country	2 Open Country, Scattered obstructions
Height above ground (m)		
3 or less	0.83	0.72
5	0.88	0.79
10	1.00	0.93

The factor S_3 takes account of the degree of security required and period during which there will be exposure to wind. Fig 2 shows values of S_3 equivalent to a 50 year exposure period plotted against the period in years.

Wind loads on windbreaks would probably be required for lesser periods such as 5 to 20 years exposure periods. It must be remembered that whatever wind speed is adopted for design purposes there will be a probability that it may be exceeded; the greater the period of exposure the greater the probability.

(Fig 2 indicates, there is a 63% chance that the '50 year gust' will be exceeded in that period).

Fig 2 shows that the 1 in 5 year wind gust (at 10 m over open country) is obtained by scaling the 1 in 50 year gust by 0.83.

Method of calculating F

Knowing V, S_1, S_2 and S_3 then V_S can be calculated by equation 3 using tables 2, 3 and Fig 2.

Values of q in equation 2 are then found from table 4,5 and 6 and fig 3 which present q in SI, metric, and imperial units.

C_f in equation 1 is then found for the chosen porosity from table 1; A_e is the projected area of the frame onto the wind front i.e. the 'area of shadow'.

Hence F can be calculated from equation 1.

Example

It is required to find the load likely to be encountered by a uniform wind break:

a) of 50% porosity (solidity ratio : 0.5)

b) of height H metres (H less than 3)

c) erected on undulating country (ground roughness 2) in Kent.

Step 1 : Calculation of V_S

From Fig 1 the 1 in 50 year maximum gust at 10 m (V) over open level country in Kent is about 39 m/s.

From table 2, S_1 is 1.0

from table 3 for undulating country and a wind break of below 3 m height, S_2 is 0.72.

from fig 2 for the 1 in 5 year gust, S_3 is 0.83.

Thus V_S = 39 x 1.0 x 0.72 x 0.83 m/s

$\simeq$ 23 m/s (51 mph).

Step 2 : Evaluation of q

From table 4: for V_S = 23 m/s (51 mph).

$q = 324\ N/m^2$

or 33.1 Kg f/m^2

or 6.7 lb f/ft^2

Step 3 : Calculation of F

C_f for solidity ratio of 0.5 is 1.6.

A_e for this ratio is 0.5, and H is height in metres

Thus F = 33.1 x 1.6 x 0.5 x H Kg f per metre length

= 26.5 x H Kg f per metre length

In imperial units

F = 6.7 x 1.6 x 0.5 x H x 3.25 lbf per foot length

= 18.9 x H lbf per foot length

i.e. if H is 2 metres

F = 53 Kgf per metre length

or 37.8 lbf per foot length

(~ 1/5 ton per 12 feet length)

Summary table for the British Isles

Wind loading on a 50% porous wind break, with height less than 3 m due to the 1 in 5 year maximum gusts.

1 in 50 year gust at 10 m (m/s)		1 in 5 year gust below 3 m, over undulating country m/s	mph	Wind loading Kgf/m^2	lbf/ft^2
38	(SE England)	22.8	50.8	26.0	5.3
40		24.0	53.6	28.8	5.9
44		26.4	59.0	34.8	7.1
48		28.8	64.2	41.5	8.4
52		31.2	69.6	48.7	9.9
56	(NW Scotland)	33.6	74.9	56.5	11.5

Any comments or suggestions on this paper should be referred to the author.

J R Starr
MAFF Reading
May 1978

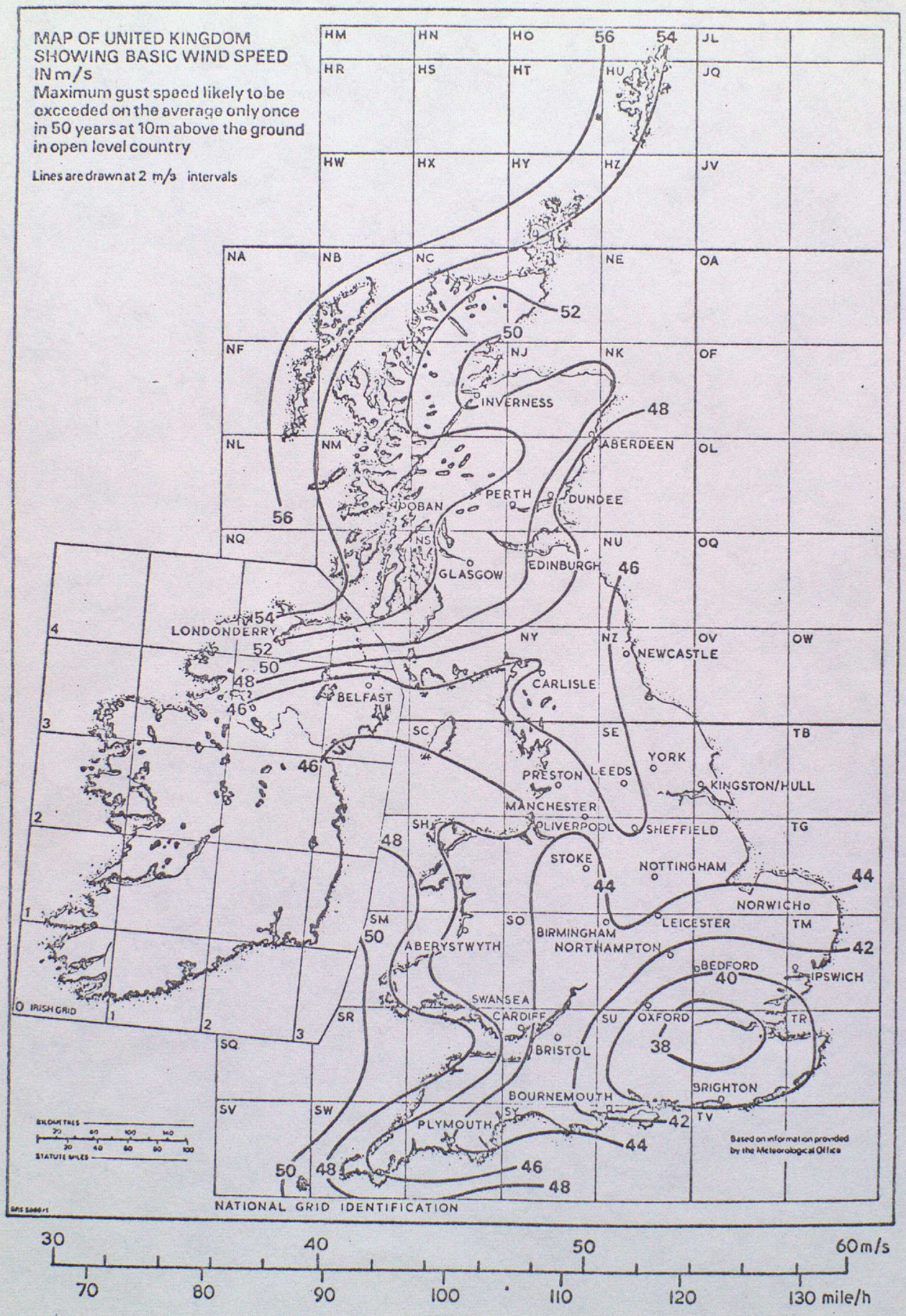
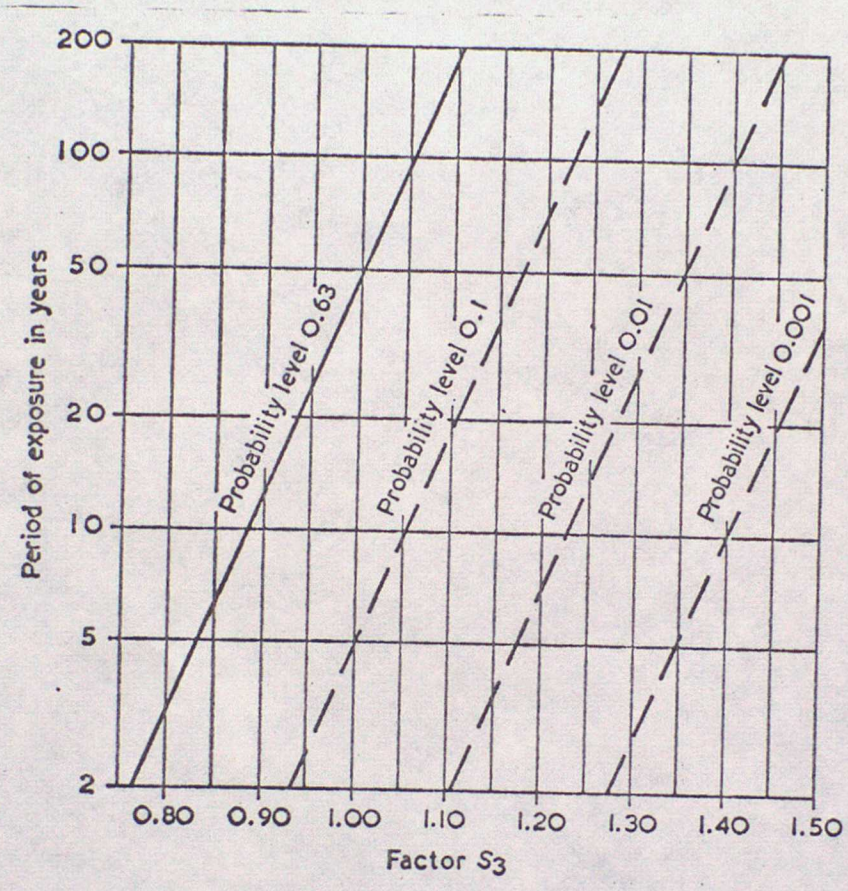


Fig. 1. Basic wind speed

Fig. 2. A statistical factor S_3



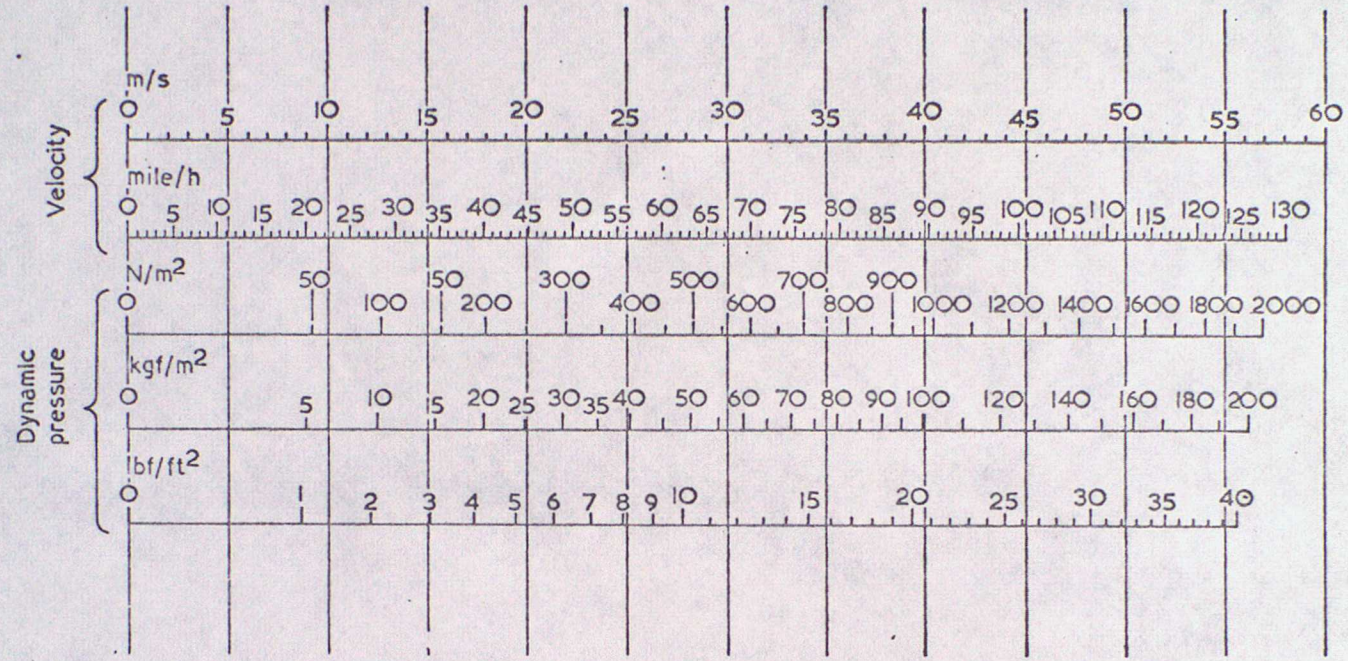


Fig. 3. Conversion chart for wind speed and dynamic pressure

. Dynamic pressure of the wind

Any vertical line traversing the scales on Fig. 3 indicates approximately the direct conversion between velocity and pressure on all three systems of units.

Table 4. Values of q in SI units (N/m²)

V_e m/s	0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
10	61	74	88	104	120	138	157	177	199	221
20	245	270	297	324	353	383	414	447	481	516
30	552	589	628	668	709	751	794	839	885	932
40	981	1030	1080	1130	1190	1240	1300	1350	1410	1470
50	1530	1590	1660	1720	1790	1850	1920	1990	2060	2130
60	2210	2280	2360	2430	2510	2590	2670	2750	2830	2920
70	3000									

Table 5. Values of q in metric technical units (kgf/m²)

V_e m/s	0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
10	6.3	7.6	9.0	10.6	12.3	14.1	16.0	18.1	20.3	22.6
20	25.0	27.6	30.3	33.1	36.0	39.1	42.3	45.6	49.0	52.6
30	56.3	60.1	64.0	68.1	72.3	76.6	81.0	85.6	90.3	95.1
40	100	105	110	116	121	127	132	138	144	150
50	156	163	169	176	182	189	196	203	210	218
60	225	233	240	248	256	264	272	281	289	298
70	306									

Table 6. Values of q in imperial units (lbf/ft²)

V_e mile/h	0	1	2	3	4	5	6	7	8	9
30	2.3	2.5	2.6	2.8	3.0	3.1	3.3	3.5	3.7	3.9
40	4.1	4.3	4.5	4.7	5.0	5.2	5.4	5.7	5.9	6.1
50	6.4	6.7	6.9	7.2	7.5	7.7	8.0	8.3	8.6	8.9
60	9.2	9.5	9.8	10.2	10.5	10.8	11.2	11.5	11.8	12.2
70	12.5	12.9	13.3	13.6	14.0	14.4	14.8	15.2	15.6	16.0
80	16.4	16.8	17.2	17.6	18.1	18.5	18.9	19.4	19.8	20.3
90	20.7	21.2	21.7	22.1	22.6	23.1	23.6	24.1	24.6	25.1
100	25.6	26.1	26.6	27.2	27.7	28.2	28.8	29.3	29.9	30.4
110	31.0	31.5	32.1	32.7	33.3	33.9	34.4	35.0	35.6	36.3
120	36.9	37.5	38.1	38.7	39.4	40.0	40.6	41.3	41.9	42.6
130	43.3	43.9	44.6	45.3	46.0	46.7	47.3	48.0	48.8	49.5
140	50.2	50.9	51.6	52.3	53.1	53.8	54.6	55.3	56.1	56.8
150	57.6									